Figure *1*

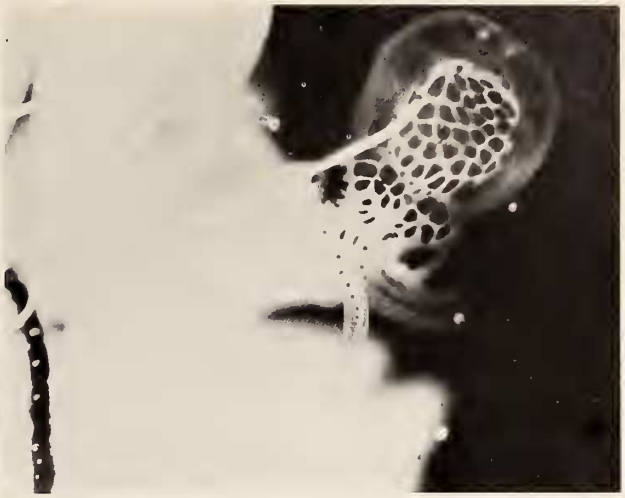

Figure *3*

Figure *2*

Figure *4*

Figure *1*: During mating, the male remained positioned above the female (photo by S. Gabe)
Figure *2*: Brooding of the eggs by the female (photo by Dr. Pierre Dow)
Figure *3*: A juvenile emerges backward from its egg capsule (photo by Finn Larsen)
Figure *4*: A brine shrimp in the jaws of a juvenile octopus (photo by Dr. Pierre Dow)

Hatching began late during the first week of October after a brooding period of 160 days. The water temperature had reached 12.8°C. The hatching process continued until mid-December during which period the temperature dropped to 10°C. With the mother dead, hatching in the latter weeks occurred only when the author agitated the egg masses.

Repeated contractions and expansions of the mantle by the embryo finally succeeded in breaking the distal end of the capsule. The young octopus then emerged backwards from the egg (see Figure *3*). The hatching process lasted several hours. Occasionally in its struggle to emerge, the embryo expelled a small puff of ink, with no apparent consequence to its health. Often the yolk was lost during hatching, or shortly thereafter, by the active juvenile.

e) **The Juveniles:** Upon emerging from the egg, the young immediately swam with jerky movements to the surface. Their most conspicuous features were the large dark eyes, the ventral ink gland and the spotted pattern of large brown chromatophores lining each arm and on the dorsal surface of the head and mantle. They remained pelagic, only intermittently sinking to the bottom for short times. Extensive periods by a juvenile on the floor of the tank generally indicated an unhealthy individual.

With each expulsion of a jet of water from the siphon, the young octopuses moved backwards for distances ranging from a few millimeters to approximately 30 mm. They swam in both horizontal and vertical planes. In the vertical plane they swam upwards only, passively sinking downwards. Their exhalation rate during swimming averaged 98 per minute. During periods on the bottom, the average was 48 per minute in a healthy animal. This contrasted with the resting exhalation rate of an adult (then on display at the Vancouver Public Aquarium) which averaged seven per minute.

The juveniles were offered a variety of foods that included crushed egg yolk, ground shrimp and mussel. live gammarids, live brine shrimp (both young and adult stages) and fry of the red Irish lord sculpin *(Hemilepidotus hemilepidotus)*. Of these, only the fry and the adult brine shrimp appeared to be accepted and then only when offered in sufficient quantities. If supplied in small quantities, both the fry and the shrimp were untouched. In densities of 100-120 per liter, shrimp were frequently observed in thejaws of juvenile octopuses (see Figure *4*). The juveniles developed an orange pigmentation, corresponding to the colour of the shrimp, suggesting that the shrimp were in fact being ingested. Occasionally, dead siblings were also seen in the jaws of surviving juveniles.

Unfortunately, by the time the preferred food and the optimal food density had been determined, only a small number of juveniles remained. These died when a city power failure cut their water supply, leading to fouling in their tanks.

DISCUSSION

Typical of octopods, the egg care behaviour of *Octopus dofleini martini* was strongly developed and agitation of the egg masses was continuous. On those few occasions when the female moved away from her clusters, at least one arm maintained active contact with them. Furthermore, she continued brooding despite the trauma of her accident and the subsequent amputation.

As Brough (1965) pointed out, the death of a brooding mother after the hatching of her young appears to be a common occurrence among octopods. A general weakening caused by starvation accounts for most of the deaths observed in the laboratory. Furthermore, a number of divers have observed the emaciated carcasses of female octopuses still inside their dens, surrounded by empty egg cases (personal communication), suggesting that the female's death—presumably from starvation—is a frequent occurrence in nature as well.

The fate of the male is also uncertain. In the present study, the male died about 54 days after mating. Similar results were obtained in a second mating conducted at the Vancouver Aquarium in the spring of 1974. The second male, however, was donated to the Aquarium by Sealand of the Pacific, Victoria, after a breeding season during which a number of females had been successfully fertilized. It may be that the male is capable of numerous matings but survives only one breeding season. Both of the author's observations were in fact made late in the breeding season.

Spawning began 42 days after mating. Egg deposition continued from April 27 until May 11. Hatching began 160 days after initial spawning. Water temperatures from spawning to initial hatching ranged from 9.2° to 13.9°C. Hatching began when the temperature was 12.8°C and lasted 78 days, during which time the temperature dropped gradually to 10°C.

The hatching rate was highest during the first two weeks. Had the mother survived, hatching may not have extended 78 days. Without her constant attention, the process was restricted to those periods during which the author herself agitated the egg masses. Most of the juveniles hatching late emerged without the yolk.

In Okubo's study (1973), *Octopus dofleini dofleini* also spawned for 15 days and, as in this study, the female also appeared to deposit her eggs exclusively at night. Due to

abnormally rough maternal behaviour, Okubo had removed 20 clusters of eggs and kept them in a tank with the incoming water aimed directly at the clusters to prevent debris from accumulating on their surfaces. A period of 150 days passed in this fashion before hatching began. The DML of emerging juveniles averaged 5.4 mm as compared with only 3.51 mm for *O. dofleini martini*. These figures reflect a higher growth rate for *O. dofleini dofleini,* probably due in part to the higher water temperatures in the Japanese study: from spawning until initial hatching, the water temperature varied between 15.3° and 12.5°C.

Eggs of *Octopus dofleini dofleini* required 40 days to complete hatching (Okubo, 1973). The success of hatching within the 20 clusters was over 62% despite the lack of maternal brooding. The rate in the present study was at least that high despite the absence of active stimulation by a female in later periods.

Feeding the juveniles presented one of the major problems. As Okubo (1973) also observed, they fed only on material in suspension, and ideally live plankton would probably provide the optimal food source.

ACKNOWLEDGMENTS

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Erratum: The credit for Figure 2 should read
(photo by S. Gabe)

Egg and Larval Development in the Green Mussel, *Mytilus viridis* Linnaeus

BY

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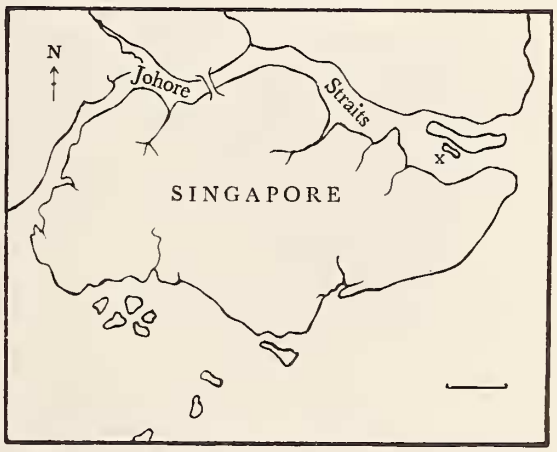
(2 Plates)

INTRODUCTION

The normal development of fertilised *Mytilus edulis* Linnaeus, 1758 eggs has been described by Wilson (1886, quoted by White 1937), Matthews (1913), Field (1922) and more recently by Rattenbury & Berg (1954) and Wisely (1964). No work has previously been done on any aspect of reproduction in the green mussel *Mytilus viridis* Linnaeus,1758. Are there any differences (*e.g.* temporal, embryo size) in the development of *M. viridis* eggs and larvae?

To follow the development of the egg from the time of fertilisation, mature mussels had to be induced to release their spawn separately before artificially fertilising the eggs. This paper reports a generally successful method of inducing gravid *Mytilus viridis* to spawn and traces the development of the fertilised egg until metamorphosis.



Map of Singapore showing localities mentioned in the text
scale = 5 km

MATERIALS and METHODS

Mature mussels (shell lengths 5–8 cm) were collected at intertidal levels from the Serangoon Harbour area in the Johore Straits (see Map, position marked X), by gently cutting their byssal attachments to submerged wooden poles. The animals were transported to the laboratory in moist cloth bags. Care was taken to ensure minimal exposure to the sun or heat. Water (salinity range 28 to 30 ‰) was collected at the same time and locality as the mussels.

The mussels were kept for 10 to 14 days in 10-lit. jars of sea water at 23°–25° C. They were unfed. Initial fears that the gonads would degenerate on keeping proved to be unfounded as the results of the experiment on induced spawning show. The water was then changed with freshly collected or stored sea water at the same temperature. Stored water refers to sea water that has been kept in the laboratory for at least two weeks. If spawning did not occur within 6 hours of the stimulation, the mussels were discarded. The experiment was repeated twenty times between January 1970 and January 1972.

Spawning mussels were transferred individually into shallow glass dishes containing sterilised sea water. About ten thousand eggs were pipetted into each of several 1-litre glass beakers (culture vessels) containing sterilised sea water. Methods for quantitative assessment of eggs are given by Wisely (1964) and Tan (1973). A few drops of sperm were introduced into each culture vessel and the whole suspension agitated. Egg and larval samples were frequently pipetted from the suspension and examined under the microscope (× 100, × 400). The process of development was observed and photomicrographs were taken.